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(71) Applicant and
(72) Inventor: MUTHUNAYAGAM, Abraham, Ebenezer [IN/IN]; 2 FIB West Luthern Street, Nagercoil, Tamil Nadu - 629001 (IN).

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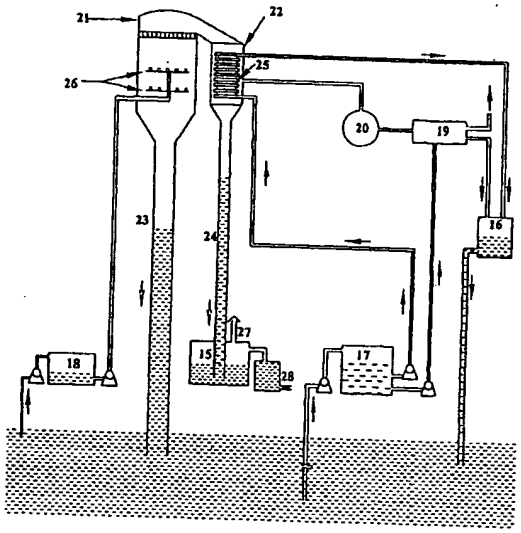
(54) Title: A PROCESS, SYSTEM AND DESIGN FOR DESALINATION OF SEA WATER



(57) Abstract: This invention relates to a process and a system for generating potable water from sea water. The process is a low temperature flash evaporation process for desalination. The water vapor, free from dissolved matter condenses on fresh water in a condenser maintained at low pressure. The vaporizer and the condenser are maintained at low pressure by a vacuum pumping system and barometric seals. The hydrostatic pressure, discharges unevaporated feed water and condensed fresh water without any additional pumping system. The vacuum pumping system consists of ejectors, primary water jet ejectors and mechanical vacuum pumping devices. The low temperature sea water from ocean depth is pumped at a higher pressure as driving fluid in the water jet ejectors to produce necessary vacuum for operation of the system.

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A PROCESS, SYSTEM AND DESIGN FOR DESALINATION OF SEA WATER

FIELD OF INVENTION

This invention in general relates to human necessities. Further, this invention is concerned with the generation of fresh potable water using a novel concept. More particularly, the instant invention relates to a process, system and design for desalination of sea water to produce fresh water from sea water utilizing effectively the solar energy stored in the sea.

At the outset of the description which follows, it is to be understood that ensuring description only illustrates a particular form of this invention. However, such particular form is only an exemplary embodiment, and without intending to imply any limitation on the scope of this invention. Accordingly, the description is to be understood as an exemplary embodiment and reading of the invention and not intended to be taken restrictively.

It is to be noted that the prior art descriptions give in detail information of the technology, method, process and system known in the art. They indicate the improvements in the related art and the object of the invention being to overcome or surmount the deficiency associated with the prior art. This forms the essential feature and the object of the invention.

BACKGROUND OF THE INVENTION

The salient feature of the invention is the production of fresh water economically from sea by using warm water from the upper strata of the sea which is flash evaporated at low pressure in a vaporizer and

condensing the vapour in a condenser, also maintained at low pressure using the cold sea water taken from a depth below 150 metres without using any external energy for heating and cooling. External energy is supplied only for circulating the sea water through vaporizer and condenser at desired flow rates and maintaining the low pressure in the system by appropriate vacuum pumping system, which consist of ejectors, vacuum pumps and barometric seals.

It is a known fact that 97.2% of the world's water is in the oceans and contains such high concentrations of sodium and magnesium as to be unfit for either human consumption or most industrial applications. An evaporation method was used by Greek sailors of the 4th century BC for desalting water.

In the present scenario, distillation remains the most widely used desalination process. Either a multiple effect or a flash evaporator may be used. The first consist of a series of evaporators in which salt water is heated and vaporized. The hot vapor is used to heat salt water entering the next evaporator; in doing so, the vapor is cooled and condensed into fresh water. Since the multiple effect evaporator reuses heat, it requires less energy than a single evaporator.

In flash evaporation, generally heated seawater is sprayed into a chamber kept under reduced pressure. At this reduced pressure, the water vaporizes at lower temperature, so that the flash evaporators require comparatively less energy.

It is a known fact that water is the most precious resource needed by man and all the living organisms of the earth. This is essential for domestic, industrial and agricultural purposes. A survey of water

resources reveals that there is an enormous quantity of fresh water available on earth but that is poorly distributed. The tremendous growth of population and industry, rapid demographic expansion of developing countries and improvement in standard of living in developed countries have led to taxing of available water supplies by overdraft and pollution even in locations known to have adequate water resources. Also less than 2% of the water on earth is only fit for drinking and sustenance of life. There have been global developments and agriculture which have necessitated to seek alternate sources for fresh water. Desalination of water is identified as one such resource for obtaining potable water. Desalination may become desirable in regions poorly supplied with fresh water but contain plenty of saline waters. Development and application of reliable desalination techniques allowing to produce fresh water economically remain a major challenge for humanity.

The dissolved salts have to be separated out from the saline water. The process of desalination as is known widely could be achieved by several means such as ion exchange processes, membrane processes including electro dialysis, reverse osmosis; process based on change of states including freezing, distillation, vapor compression and the like. As on today, it is estimated that among the total installed capacity of fresh water production adopting all these processes, a very large percentage is through distillation process.

The average salt content of seawater is about 35g/l. Computations reveal that the theoretical energy necessary to desalt one cubic meter of seawater is about 0.7 KWH, though the actual energy consumption could be much higher. The entire economics of the desalination industry depends upon the question of how the energy for desalination process could be made available. The most obvious solution lies in the

use of fossil fuels, if it could be available cheap. In the case of solar energy as an alternate, the capital cost of solar energy collecting devices is extremely high though the cost of energy production is negligible. Comparison of estimates of capital costs reported in literature for a large scale desalination system using fossil energy and solar energy indicates that use of solar energy by collecting it by conventional means does not appear to be an economically viable solution for the desalination process.

PRIOR ART

A search for patents in the relevant technology using various databases was conducted. From the search the following related patents are identified. A thorough examination of patent has been done. The data of related patents and result of the finding are as follows:

Patent No.	*Title*
6,190,556	Desalination method and apparatus utilizing nano filtration and reverse osmosis membranes
6,180,012	Sea water desalination using CO2 gas from combustion exhaust
6,158,239	Desalination through gas hydrate
6,139,750	Water desalination
6,132,613	Centrifugal reverse-osmosis desalination unit incorporating an annular membrane cartridge
6,103,502	Ultrafiltration process for desalination and concentration in a cell-free fermentation medium
6,103,125	Zero waste effluent water desalination system
6,083,382	Water desalination system
6,080,315	Process for the partial desalination of water

6,036,830	Desalination of aqueous sulphonamide solutions
5,997,737	Portable skid mounted desalination apparatus
5,932,074	Method and an apparatus for the desalination of seawater
5,873,262	Desalination through methane hydrate
5,853,549	Desalination of seawater by evaporation in a multi-stack array of vertical tube bundles, with waste heat
5,744,008	Hurricane tower water desalination device
5,685,980	Miniaturized handheld desalination field unit
5,679,254	Desalination of seawater by nonionic surfactant aided phase separation
5,672,250	Seawater solar desalination system
5,650,050	Device for the desalination of seawater
5,589,050	Electrodialyzer for desalination
5,553,456	Clathrate freeze desalination apparatus and method
5,552,022	Desalination system utilizing transfer conduit extending above salt water siphon height
5,547,586	Method and apparatus for the desalination of salt containing water
5,534,118	Rotary vacuum distillation and desalination apparatus
5,520,816	Zero waste effluent desalination system
5,512,176	Desalination process

The aforesaid patents cover the field of technology and system of generating potable water using the process of desalination of sea water in addition to the other patents discussed below.

In French Patent 2.511.667 an apparatus is described which contains a transparent plaque under which desalination of water is obtained by condensation.

In French Patent 2.524.335 a multiple effect distillation apparatus comprises an enclosure separated by dividers into super imposed compartments. During the day solar energy heats the water in the bottom compartment and causes evaporation. During the night vapors are condensed in the upper compartment.

German Patent 3.123.084 describes an apparatus consisting of a solar heater, a seawater flash chamber and a condenser for water vapor collection, connected to a freshwater withdrawal conduit.

Indian Patent 150.924 describes a portable solar still which has an inclined transparent sun-exposed face and darkened moulded base and sides to form a box type still. This evaporation unit is suitable for desalination of small quantities of brackish water.

In U.S. Patent 4.337 a system of pumps, controls and an accumulator ensures that solar heated sea water is collected while the sun shines and the supply of feed water to the evaporator continues when the sun is not shining.

In U.S. Patent 3,986,938 a low boiling water immiscible medium is directly contacted in liquid state with relatively hot and warm water and in vapor state with relatively cold water wherein the thermal energy is transferred between the phases so contacted for the purpose of evaporating the immiscible liquid in an energy production system and evaporating saline water in a desalination system.

U.S. Patent 4,204,914 describes an apparatus and a method for removing the contaminants from water having solid contaminants dissolved therein by utilizing solar energy to heat the water. The heated

water is exposed to the vacuum conditions by an evaporator means so that the temperature of water is above saturation temperature. The water is thus vaporized and solid contaminants dissolved therein are separated therefrom.

U.S. Patent 4.383.891 describes that solar energy is focused on some of the brackish water inside an enclosure. The vapor formed is condensed by heat exchange with a coolant circulated from outside the enclosure and the pure water so formed is removed from the enclosure.

U.S. Patent 5,064,505 describes a system designed for a low pressure desalination in a water chamber having an open end submerged in an ocean. An air exhaust pump draws air out of water chamber to lower the surface tension of an upper stratum of water which is thereby converted to vapor and subsequently condensed to nonsalinated water and collected in a U-shaped trap with a pair of sealing closable valve.

In Japanese Patent 83.20286 an apparatus is described which comprises a solar radiation collector, a compressor, a heat exchanger, evaporators, condensers and adiabatic device Freon or an alcocholis used as heat transfer medium in heating the feed solution.

In U.S. Patent 4.376.687 solar heated feed solution is kept in storage tank from which it is fed to a flash evaporator. The vapor from the flash operator is used to heat the first effect evaporator of a multiple effect evaporator to which the unevaporated solution from the flash evaporated is fed.

German Patent DE 3.119.615 describes a system in which the air taking up the evaporating seawater is drawn through a space between the

water surface and the solar heat absorbing cover by a flue duct action. The cover and the air drawn under it are heated by the solar radiation. The wet air is then indirectly cooled by cold seawater so that the desalinate condensate is collected in a container before the air leaving the flue.

W. German Patent 3,132,868,3 describes a solar multistage flash evaporation desalination unit coupled to an absorption heat pump where heat is stored during the day by endothermic desorption and used at night to preheat sea water.

Desalination by distillation had been widely used to obtain fresh water. Most known distillation devices suffer a common drawback of inefficiency and have limitations for use in large-scale applications. This inefficiency results in either low outputs of pure water or in extremely high power requirements. The known devices requiring high power inputs result in unacceptable environmental impacts. In addition, the fresh water thus produced requires addition of small quantities of minerals for making them suitable for human consumption.

The solar energy has been the most prominent of alternate source of energy for desalination. The solar energy is commonly utilized at vaporization step in the distillation process. For this the device must be quite large in size covering large areas and requiring large solar energy transfer device.

Present invention obviates the disadvantage of prior art and provides a system which is compact without requiring additional sources of energy supply such as solar pond, boilers and large structures as is used in other configurations to heat the feed water. Depending upon the

location of the plant, it can have on board generator or power supply through cables from shore for the supply of electrical energy for circulating sea water and maintaining desired vacuum in the system according to the process requirements.

Desalination through phase change – Vaporization and condensation – is a well-known and widely adopted process. As explained earlier, in this process under this invention, the warm seawater from the upper strata of the sea at temperature above 20° C is flash evaporated at low pressure in a vaporizer and this vapor is condensed in the condenser by the cold seawater below 20° C, taken from water depth of below 150 m. There is no external energy supply for heating the feed water. External energy is supplied only for circulating the seawater through vaporizer and condenser at desired flow rates and maintaining the low pressure in the system by appropriate vacuum pumping system, which consists of ejectors, vacuum pumps and barometric seals.

SUMMARY OF THE PRESENT INVENTION

The extensive study of the patent specification in the related art reveals that energy cost is the major constraint in all technology so far known in the art. Therefore the inventor has identified the need to overcome the problem inherent in the prior art technology. Having addressed to the problems associated with prior art technology the inventor proposed the novel solution in the form of a process, a system and a design for generating potable water from sea water using maximally the solar energy stored in the sea water.

The present invention addresses itself in making use of the solar energy, stored in the sea at different depths mainly for separation of dissolved salts from seawater in an economically viable manner. The

novelty of the invention is that unlike the conventional processes, the solar energy, is not collected as it is radiated from the sun, but is collected from its dormant state. The transfer of this stored energy in the sea is made possible by taking advantage of the temperature driving potential existing in the varying depths of water in the sea.

Another feature of the invention is to develop a process and system which is compact and to maximally use the solar energy stored in the upper strata of the sea water and depths thereby requiring no additional sources of energy supply such as solar pond, boilers, large structures to receive solar energy etc. to heat the feed water in producing fresh water.

The basic scheme of separation of salt from water by a phase change process (distillation) in the conventional system is in two steps: - In the first step the water is preheated by external energy and flash evaporated and thus separated from salts and brought to a vapor state. In the second step, the vaporized water is brought back to the liquid state by condensing it using water at ambient conditions as a coolant.

In the present invention, the seawater from the upper strata of the sea is flash evaporated in a vacuum vessel and no external heat is supplied for preheating the feed water. The generated water vapor is at a temperature lower than the ambient. For the second step of condensing the vapor, the cooling water has to be at a much lower temperature, and hence the cold water available from the ocean depth below 150 m from surface is used. The entire process does not make use of any external source of energy other than that needed for operating the pumps for feed water, cooling water and vacuum pumping system. The solar energy stored in the upper surface of the ocean is used to the maximum

possible extent.

The present system according to this invention provides for two system configurations depending upon the bathymetry and user location. In the first embodiment the system is barge-mounted and moored at appropriate water depths. The barge has normally a moon pool at the centre through which seawater intakes and discharges are made by suitable pipes and ducts. The entire system including the power supply is mounted on the barge. The fresh water is collected from the barge and transported to the users. This system configuration could provide fresh water to off shore activities as well.

In the second embodiment, the system is shelf mounted in shallow waters or on shore with provision to receive warm seawater from the upper strata of the sea and cold sea water from depths. This could receive electrical supply from shore stations which also has facilities to receive, store and transport fresh water to different users.

The foregoing description outlined rather broadly preferred and alternative feature of the present invention so that those skilled in the art may better understand the detailed description of the invention that follows. Additional features of the invention will be described hereinafter that form the subject of claims of the invention. Those skilled in the art should appreciate that they can readily use the disclosed conception and specific embodiment as a basis for designing and modifying other structures for carrying out the same purposes of the present invention. Those skilled in the art should realize such equivalent conception do not depart from the spirit and scope of the invention in its broadest form.

The primary object of the invention is to invent a novel process of

desalination of sea water.

Another object of the invention is to invent a novel system for desalination of the sea water.

Another object of the invention is to invent a design for desalination of sea water which is compact and use the maximum solar energy stored in the sea water.

It is another object of the invention to invent a novel system for desalination of sea water which utilizes least energy for producing fresh water.

Further objects of the invention will be clear from the ensuing description.

Accordingly, the present invention relates to a system for desalination of water to produce fresh water from seawater comprising:

- means for collecting and storing warm seawater above 20°C from the upper strata of the sea, cold seawater below 20°C from the deeper cool strata of the sea and fresh water produced in the system.
- vaporization means comprising a chamber and an injection device having plurality of jets to atomize the warm water from the upper strata of the sea into fine particles connected to said storing means for warm water.
- outlet means provided at the bottom of the said vaporization means for discharge of unutilized seawater into the sea at desired depths.
- condensation means comprising a heat exchanger placed

separately or integrally with the said vaporization means to condense the vapour produced in the above said vaporization means.

- means for storing and supplying the cold water from ocean depth to heat exchangers in the said condensation means for condensing the vapour produced in the vaporization means and discharging this cooling water coming out of the heat exchanger into the sea.
- means for creating vacuum comprising vacuum chamber and pumping devices connected to the said condensation means, vaporization means and associated equipments
- means for controlling and maintaining the vacuum level in the vapouriser, condenser etc.; levels of feed water and cooling water in the storages; the flow rates of feed water into vapouriser and cooling water to the condenser and other physical parameters as required by the process.

The present invention also relates to a process for desalination to produce fresh water from seawater comprising:

- filling the fresh water storage, cold water storage and warm water storage to the specified level.
- creating a vacuum in the vacuum chamber to reduce the pressure in the vaporization means and condenser means to the specified level.
- supplying the cold water having the temperature below 20°C to the heat exchanger in the condensation means at the required flow rate to maintain required temperature as per the process requirement.
- injecting the warm water having the temperature above 20°C into the vaporization means at the desired flow rate through injecting

device.

- flash evaporating the injected warm water at the low pressure and directing the vapours to flow through the heat exchanger in the condensation means.
- collecting the unevaporated water at the bottom of the vaporization means and discharging the said water into the sea at required depth appropriately distributed for safe and sustainable marine ecological systems.
- condensing the vapours flowing through the heat exchanger and collecting the condensed vapours into the fresh water well.
- controlling and maintaining the process parameters like water levels, water flow rates, vacuum and pressures according to the process requirements.

The present invention also relates to a design configuration of a system for producing fresh water from sea water comprising the following:

- An Injector configuration with a cavity having tangential entry of sea water and axial discharge of it as conical swirling jets into vapouriser.
- An Injector module consisting of a number of injectors arranged circumferentially in single or multiple rows at different radie around a central hub serving as a source for supply of the sea water at desired flow rates through radial flow paths to injectors with provisions to increase or decrease the number of injectors in a injection module.
- An Injector module cluster with one or more injector modules mounted on a duct feeding the sea water to the injectors through the injector modules.
- An injector system consisting of one or more injector module cluster with identical coaxial injector module pairs facing each

other and placed at distance apart in parallel planes enabling the swirling conical jets issuing from the injectors in one plane to impinge with corresponding swirling conical jet issuing from the other with provision for increase or decrease in the number of injectors.

- A manifold system feeding the sea water to the injection module assemblies at the desired pressure and flow rates.
- A vapouriser with a chamber of required volume with the injector assembly suitably located inside the chamber and having appropriate inlet connection to the manifold system to feed the sea water and an outlet preferably at the bottom of the chamber, with a long duct connecting the outlet to the sea and the duct providing the barametric seal during operations
- A condensing system with one or more number of condensers with shell and tube and or plate heat exchangers connected to the vapouriser with proper ducts to ensure smooth passage for the vapours produced in the vapouriser to the condensers and to ensure complete condensation of all vapours as fresh water.
- A vacuum pumping system with vacuum pumps and ejectors connected to one or more numbers of vacuum bottles and the condensers for maintaining the desired vacuum pressure in the condenser and vapouriser

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS

Fig. 1 illustrates the System Block Diagram illustrating the process flow and control system.

Fig. 2 depicts the desalination system having five subsystems:

Figure 3 shows the configuration of one such injector used in the injection system

Figure 4 shows the configuration of the injector module having plurality of injectors

Figure 5 shows the configuration of the injector module assembly having plurality of injector modules

Figure 6 shows the configuration of the injector assembly having plurality of injector module assemblies

Figure 7 shows the configuration of vapouriser-condenser assembly

These drawings are meant for illustration purpose and should not be construed as a limitation to the invention.

DETAILED DESCRIPTION OF ONE EMBODIMENT OF INVENTION

In the invented system illustrated in Fig.1, a novel concept of a desalination system and process is evolved whereby sea water from the upper strata of the sea at the ambient temperature without preheating is flash evaporated in a vertical vaporizer maintained at a low pressure. The water vapor, free from dissolved matters condenses as fresh water in a condenser also maintained at low pressure. The vaporizer and condenser are maintained at low pressure by a vacuum pumping system and barometric seals. The hydrostatic pressure discharges the un-evaporated feed water and the condensed fresh water without any additional pumping system. The noteworthy feature of the concept is that while the feed brine is drawn from the relatively warm surface of the sea, the coolant for the condenser is drawn from the relatively cold

water, from the depth of the ocean. The temperature difference between the seawater at the strata of the sea and at depth provides the necessary driving potential. The vacuum pumping system consists of ejectors, primarily water jet ejectors and mechanical vacuum pumping devices. The low temperature seawater from ocean depth is pumped at high pressure as driving fluid in the water jet ejectors to produce the necessary vacuum for operation of the flash vaporizer. The absence of preheating of feed and use of low temperature sea water from depth for condensing vapour and operation of the ejector system could make the scheme energy efficient and cost effective. Systems could be developed based on this concept for different applications in agricultural, domestic, industrial and off shore programmes. The system block diagram of the concept is given in fig.1

Figure 1 of the drawing identifies and links various parts of the system. Control system with distributed sensors and control devices are denoted by (1) and the linkages by (14) and vacuum pumping system and vacuum storage by (2). The feed water from the upper strata of sea (7) is stored in the Feed Water Storage (3) and injected through multijets into the Vapouriser system (4) to aid flash evaporation. Unevaporated feed water is returned to the sea (8) from vapouriser system (4). The water vapour coming out of the vapouriser is passed into a low pressure heat exchanger in the Condenser system (5). Cold water from depth of the sea (10) is stored in a Cooling Water Storage (13) from which it is circulated to Heat Exchanger in low pressure condenser system (5) for condensing the vapour coming out from Vapouriser system (4). The cooling water outlet from Heat Exchanger in Condenser system (5) is discharged into the sea (9). The fresh water from condenser is stored in a fresh water storage (6). The cooling water from storage (13) is also supplied to the water jet ejector in the vacuum pumping system (2)

which has a provlsion for gas discharge to the atmosphere (11) and liquid discharge to sea (12). The control system (1) with linkages (14) maintains the vacuum and liquid levels and the flow rates at the desired values according to the process requirement.

The invented system can be a barge-mounted system, moored at suitable water depth or shore/shelf mounted system with necessary piping system to supply required warm seawater from upper strata of the sea and cold water from depth. This option of the layout depends upon the bathymetry at the site of the plant.

The process of desalination of sea water comprises the following steps.

a) Storing of feed water taken from upper strata of the sea.
b) Vapourisation of feed water with injectors to aid flash evaporation using vapouriser module maintained at low pressure with the aid of vacuum pumping module and barametric seal.
c) Storing of cooling water taken from ocean depth.
d) Condensation of water vapour using low pressure condenser module and using cooling water taken from ocean depth and barametric seal for fresh water collection.
e) Storing of fresh water.
f) Vacuum pumping for maintaining desired vacuum in vapouriser - condenser module and associated means and barametric seals.
g) Controlling the entire process by means of a control system with distributed sensors and control devices.

Fig. 2 depicts the desalination system having five subsystems:

They are :

a) Vaporizing and condensing system consisting of vaporizer with special injection system and condenser with heat exchanger.

Both vaporizer and condenser can be separate units or integrated units with barometric seals.

b) Vacuum pumping system with vacuum chamber and combination of ejectors and vacuum pumps.

c) Cooling system to condense the vapors using cold seawater, taken from depths.

d) Storage system for Warm sea water from upper strata of the sea, Cold sea water from lower strata of sea and Fresh water.

e) Instrumentation and control system including power supply.

In a typical operation of the invented system (Fig.2), though variations are possible the fresh water is filled in the fresh water well (15) to the specified level. The water levels in the deep sea cold-water storage (16 & 17) and warm surface water storage (18) are maintained at the specified levels. Vacuum pumping module (19) is turned on. After specified level of vacuum is reached in the vacuum chamber (20) the control valves are operated and the pressure in the Vaporizer module (21) and condenser module (22) is reduced to the specified level. The sea water level in the duct (23) and fresh water level in the duct (24) rise as vacuum builds up. Cold water is circulated through the heat exchanger (25) in the condenser module (22) at the required flow rate. The warm water from (18) is injected at the desired flow rate after required temperature is established in the heat exchanger (25) into the vaporizer module (21) through specially designed injection system (26) with devices to atomize the feed water into fine particles to provide large surface area to increase the evaporation rate.

The injected warm water flash evaporates at the low pressure and vapour flows through the heat exchanger (25) in the condenser module(22). The water that is not evaporated collects at the bottom of the vaporizer module (21) and is discharged into the sea at required depth through the long discharge duct (23) at the bottom of the vaporizer module (21) which is partially filled with sea water and thus providing the barometric seal. Vapour flowing through the heat exchanger condenses and flows down to the fresh water well(15), through the duct (24), which provides the barometric seal due to the height of the column and the vent (27) providing atmospheric pressure. From the well fresh water is collected into the fresh water storage (28) and pumped to on-shore facilities or transported for use as required.

The control system ensures the supply of the specified quantity of fresh water by sensing and processing selected parameters during operation of the plant and operating the control system. The control system is provided with five control loops. The first one is for maintaining a constant level in the feed water storage tank. The level of the feed water is sensed by a level indicator and transmitted to the control unit, which processes the signal and commands an on-off control valve, which regulates the feed water supply to the feed water storage tank. The second one is for maintaining a constant level in the storage tank for cold water taken from ocean depth. The level of the cold water is sensed by a level indicator and transmitted to the control unit, which processes the signal and commands an on-off control valve, which regulates the cold-water intake to the storage tank. The third one is for injecting the required quantity of feed water into the vaporizer to maintain the production of the desired quantity of fresh water. The temperature of the feed water and the pressure inside the vaporizer are sensed and transmitted to the control unit. Depending upon the

temperature of the warm water and the pressure inside the vaporizer, the algorithm computes the feed rate through the solution of the simultaneous equations governing the flash vaporization. The control system commands the position of a proportional control valve, which injects the required warm water into the vaporizer. The fourth one is for circulating the required quantity of cold water through condenser accounting for variation in the temperature of the vapour flowing into condenser. The temperature of the vapour is sensed and transmitted to the control unit. In order to condense all the vapours, the cooling water feed to condenser is regulated by operating a proportional control valve, which regulates the quantity of flow of cooling water to condenser. The fifth one is for maintaining the vacuum at the required level in the system. The vacuum in the vaporizer, condenser, and vacuum pumping system are sensed and transmitted to the control unit which processes the signals and commands the proportional control valve feeding high pressure cold water to water jet ejector or commands the operation of other back up vacuum pumping devices.

The lower end of the discharge duct (23) of the vaporizer can be connected to suitably designed under water distribution system with number of pipes discharging the water over a large area of the sea and at required depth to ensure safe and sustainable marine ecosystem.

The vacuum pumping module configured is a combination of water jet ejectors and vacuum pumps. The primary driving fluid for the water jet ejectors is taken from the deep sea coolant water storage (16) and supplied at the required high pressure by high-pressure pumps.

While particular embodiments of the present invention have been illustrated and described, it would be obvious to those skilled in the art

that various other changes and modifications can be made without departing from the spirit and scope of the invention. It is therefore intended to cover in the appended claims all such changes and modifications that are within the scope of this invention.

The system as illustrated in Fig. (2) has the following salient features:

i) The system has a special injection device (26) for injecting the warm surface water from the sea into the Vaporizer module (21). It is proposed to have a number of jets (impinging or swirl) to atomize the feed water into fine particles to provide larger surface area to enhance the evaporation rate.

ii) The Vaporizer module (21) has a barometric seal. The water, which is not, evaporated returns to the sea through a large long duct (23), the bottom of which is immersed in the sea. The Vaporizer is positioned at a height more than the barometric height above the sea surface so that under operating vacuum conditions the seawater rises and stays in the duct well below the injection plane and thus providing a seal to maintain operating vacuum in the Vaporizer and continuously discharging the injected water which is not evaporated into the sea by gravity. There is no requirement for a pump for discharging the water from the Vaporizer module (21).

iii) The lower end of the discharge duct (23) of the Vaporizer can be connected to a suitably designed under water distribution system with number of pipes discharging the water over a larger area of the sea and at required depth to ensure safe

and sustainable marine eco system.

iv) The condenser module (22) also has a barometric seal. The condenser is positioned at a height more than the barometric height above the fresh water well (15). The bottom of the condenser is connected through a long large duct (24) to the fresh water well (15), which is vented to the atmosphere. During operations, the water from the fresh water well rises in the duct (24) which connects the well to the condenser and provides the seal to maintain operating vacuum in the condenser. Condensed fresh water is continuously discharged into the fresh water well (15) by gravity. There is no pump required for discharging the condensed fresh water from the condenser.

v) The vacuum pumping module configured as combination of jet ejectors and vacuum pumps will have mainly water jets for which primary driving fluid is drawn from the deep sea Coolant Water Storage (16) and supplied at the required high pressure by a high pressure pump.

vi) The system is compact without requiring additional sources of energy supply such as solar pond, boilers and large structures as is used in other patented configurations. Depending upon the location of the plant, it can have on board generators for all its electrical energy supply or through cables from shore.

Fig.-3 illustrates the design configuration of the injector (32) having a cavity into which the sea water from the upper strata of the sea enters tangentially at (29) and comes out axially at (30) as swirling

conical jet (31) with minimum pressure drop across the injector (32). Fig.-4 illustrates the injector module (33) with 6 number of injectors (32) placed uniformly at a radius, around hub (34) with additional injector (35) at the centre of the hub (34) and the radial duct (36) connecting the hub (34) to the injectors (32) to feed the sea water at the required pressure and flow rate. The configuration design provides for increase or decrease in the number of the injectors around the hub in a radius and also increase the number of rows of injectors at a different radie around the hub (34).

Fig.-5 illustrates the injector module cluster (37) with five numbers of injector modules (33) mounted on a torroid (38) for feeding the sea water to the injectors (32). The configuration design provides for increase or decrease in the number of injector modules and also modifications of the configuration of the torroid to different shapes.

Fig.-6 illustrates the injector assembly (39) with 20 injector modules (33) mounted on 3 torroids (38) connected by a duct (40). The design provides for increase or decrease in the number of torroids and injectors and modifications in shapes. The layout of the injector modules are such that identical injector modules pairs (41) are placed coaxially to face each other in parallel planes separated by a distance enabling the swirling conical jets issuing from the injectors in one plane to impinge with the corresponding swirling conical jets issuing from the other.

Fig.-7 illustrates the vapouriser-condenser assembly with the vapouriser (42) having an injector assembly (39) with 70 pairs of impinging conical swirl jets and connected to 4 condensers (43) located around the vapourizer and 2 gas bottles (44). The configuration design provides for increase and decrease in the number of condensers, gas bottles and injectors. The utility of the vapouriser condenser assembly is to vapourise the injected sea

water from upper strata of the sea and condense the vapors produced in the condenser using the cold sea water from the lower strata of the sea as cooling water.

ADVANTAGE OF THE INVENTION

One of the advantages of the invention is that the plant can be installed at the place where the raw materials (sea water) are abundant.

Another advantage of the invention is both the process and system utilize solar energy to the maximum so that the cost of production is minimum.

Another advantage of invention is that the system can operate continuously under all climatic condition.

The plant is environmentally friendly, as the discharged water goes back to the sea without polluting the environment.

The basic object of the explanation of the invention is to indicate the salient features of the invention. The description should in no way construed as limitation of the invention. It is to be noted that within the scope and ambit of the invention various modifications or arrangements are permissible.

It will be understood that the forgoing description is only illustrative of the present invention and is not intended that the present invention is limited thereto. Many other specific embodiment of the present invention will be apparent to one skilled in the art from the foregoing disclosure. Any substitution, alteration or modifications of the present invention which come within the scope of claims are to which the present invention is readily susceptible without departing from the spirit of invention. The scope of the invention should therefore be determined not with reference to the above description but should be determined with reference to append claims along with full scope of equivalents to which such claims are entitled.

CLAIMS

1. A Process of desalination of sea water to produce potable water by using method of phase change at ambient temperature and low pressure using solar energy stored in the sea at the surface and at different depths.

2. A system for desalination of sea water using method of phase change at ambient temperature and low pressure using solar energy stored in the sea at the surface and at different depths.

3. A design configuration of a system for desalination of sea water using method of phase change at ambient temperature and low pressure using solar energy stored in the sea at the surface and at different depths.

4. A system for desalination of water to produce fresh water from sea water as claimed in claim 2. comprising the following subsystems:

a. **Vaporizing and condensing system** of vaporization with special injection system and condenser with heat exchanger, both vaporizer and condenser can be either separate units or integrated units with barometric seals,

b. **Vacuum pumping system** with vacuum chamber and combination of ejectors and vacuum pumps,

c. **Cooling system** to condense the vapors using cold sea water, taken from depths,

d. **A plurality of jets** to feed water into fine particles in the vaporizer,

e. **Storage system** for warm sea water, cold seawater and fresh water and

f. **Instrumentation and control system** including power supply.

5. A system as claimed in Claim 2 wherein the vaporizer and condenser are under vacuum for flash evaporation to take place at low pressures and temperatures.

6. A system as claimed in Claim 2 wherein there is provided a special injection device for injecting warm surface water from the sea into vaporizer, the said jet or a group of jets atomise the feed water to fine particles to provide large surface area enhancing the rate of evaporation.

7. A system as claimed in Claim 2 wherein the said vaporizer has a barometric seal wherein the water which is not evaporated returns to the sea through a large long duct, the bottom of the said duct being immersed in the sea.

8. A system as claimed in Claim 2 wherein the vaporizer is positioned at a height more than the barometric height above the sea surface so that under operating vacuum condition the sea water raises and stays in the duct well below the injection plane thereby providing a seal to maintain operating vacuum in the vaporizer and continuously discharging the injected water which is not evaporated into the sea by gravity.

9. A system as claimed in Claim 2 wherein the condenser has a barometric seal and the said condenser being positioned at a height greater than the barometric height above the fresh water well.

10. A system as claimed in Claim 2 wherein the vacuum, the pumping system being configured as combination of jet ejectors

and vacuum pumps will have water jets for which primary driving fluid is being drawn from the inlet coolent water storage and supplied at the required high pressure by a high pressure pump.

11. A system for desalination of water to produce fresh water from sea water as claimed in Claim 2 comprising:

- means for collecting and storing warm sea water from the upper strata of the sea, cold sea water from the deeper cool strata of the sea and fresh water produced in the plant.
- vaporization means comprising a chamber and an injection device having plurality of jets to atomize the warm water into fine particles connected to said storing means for warm water.
- outlet means provided at the bottom of the said vaporization means for discharge of unutilized sea water into the sea.
- condensation means comprising a heat exchanger placed separately or integrally with the said vaporization means to condense the vapour produced in the above said vaporization system.
- means for supplying the cold water from ocean depth to heat exchangers, the said condensation means for condensing the vapour produced in the vaporization means and discharging this cooling water into the sea.
- means for creating vacuum comprising vacuum chamber and pumping devices connected to the said condensation means, vaporization means, and associated equipments.
- means for controlling for vacuum building, pressure, water levels and the flow rates of feed water and cooling water.

12. A system as claimed in Claim 11 wherein the said injection device comprises a series of impinging or swirl jets connected in

series and placed inside the vaporization means.

13. A system as claimed in Claim 11 wherein the said means of storing the warm sea water is a water storage tank comprising of an inlet connected to a pipe having its open end immersed into the sea beyond two meter below the sea surface and the outlet is connected to the vaporization means through a pump or pressurization device to inject the feed water at desired pressure and flow rate.

14. A system as claimed in Claim 11 wherein the said means of storing the cold sea water are water storage tanks, comprising an inlet pipe having its outer open end placed below 150 m the sea depth and the outlet pipe is connected to the condensation means through a pump or pressurization device for circulating the cold water through the heat exchanger in the condensation means.

15. A system as claimed in Claim 11 wherein the said the means of storing the fresh water are water storage tank comprising of a vertical duct with height more than the barometric height of fresh water and connected to the said condensation means and a vent for providing the atmospheric pressure over the fresh water storage in the storage tank.

16. A system as claimed in Claim 15 wherein the said duct provides the barometric seal to the condenser at the fresh water collection means.

17. A system as claimed in Claim 11 wherein the said vaporization means is having an outlet duct for discharging water which is not

vapourised with its upper end connected to the bottom of the vaporization means and the lower end immersed in the sea at the depth below two meters from the sea surface and the duct having a height more than the barometric height above the sea surface.

18. A system as claimed in Claim 17 wherein the said outlet duct provides the barometric seal to the vaporizer.

19. A system as claimed in Claim 11 wherein the said vacuum pumping devices are ejectors and vacuum pumps.

20. A system as claimed in Claim 11 wherein the said vaporizing and condensation means are operable by control means for regulating the cold water circulation through the heat exchanger in the condensation means and warm water injection into the vaporization means at the required flow rate.

21. A system as claimed in Claim 11 wherein the said means of controlling, comprises of feed back control systems with sensor and control devices.

22. A process for desalination of water to produce fresh water from seawater as claimed in Claim 1 comprising:

- filling the fresh water storage, cold water storage and warm water storage to the specified level.
- creating a vacuum in the vacuum chamber to reduce the pressure in the vaporization means and condenser means to the specified level.
- supplying the cold water from sea having the temperature below 20°C to the heat exchanger in the condensation means at the required flow rate to maintain required temperature as per

process requirement.

- injecting the warm water from sea surface having the temperature above 20°C into the vaporization means at the desired flow rate through the injecting device.
- flash evaporating the injected warm water at the low pressure and directing the vapours to flow through the heat exchanger in the condensation means.
- collecting the unevaporated water at the bottom of the vaporization means and discharging the said warm water into the sea at required depth appropriately distributed for safe and sustainable marine ecological systems.
- condensing the vapours flowing through the heat exchanger and collecting the condensed vapours into the fresh water tank.
- controlling and maintaining the process parameters like water levels, water flow rates, vacuum and pressures according to the process requirements.

23. A process as claimed in Claim 22 wherein the temperature of the cold water circulated in the heat exchanger is below 20°C.

24. A process as claimed in claim 22 wherein the temperature of the warm water injected in the vaporizer is above 20°C.

25. A design configuration as claimed in Claim 25 which has an injector configuration with a cavity having tangential entry of sea water and axial discharge of it as conical swirling jets into vapouriser.

26. A design configuration as claimed in Claim 3 which has an injector module having a plurality of injectors arranged

circumferentially in single or multiple rows at different radie around a central hub serving as such as a source for supply of the sea water at desired flow rates through radial flow paths to injectors with provisions to increase or decrease the number of injectors in the injector module.

27. A design configuration as claimed in Claim 3 which has an injector module cluster having a plurality of injector modules mounted on a duct feeding the sea water to the injectors through the injector modules.

28. A design configuration as claimed in Claim 3 which has an injector system having plurality of injector module clusters with identical coaxial injector module pairs facing each other and placed at distance apart in parallel planes enabling the swirling conical jets issuing from the injectors in one plane to impinch with corresponding swirling conical jet issuing from the other with provision for increase or decrease in the number of injectors.

29. A design configuration as claimed in Claim 3 which has a manifold system feeding the sea water to the injection module cluster at the desired pressure and flow rates.

30. A design configuration as claimed in Claim 3 wherein a vapouriser with a chamber of required volume with the injector system being suitably located inside the chamber and having appropriate inlet connection to the manifold system to feed the sea water and an outlet preferably at the bottom of the chamber, with a long duct connecting the outlet to the sea and the duct providing the barametric seal during operations.

31. A design configuration as claimed in Claim 3 whereas a condensing system with plurality of condensers with shell and tube and or plate heat exchangers being connected to the vapouriser with proper ducts to ensure smooth passage for the vapours produced in the vapouriser to the condensers and to ensure complete condensation of all vapours as fresh water.

32. A design configuration as claimed in Claim 3 where in a vacuum pumping system with vacuum pumps and ejectors being connected to plurality of vacuum bottles and the condensers for maintaining the desired vacuum pressure in the condenser and vapouriser.

33. A system for desalination of water to produce fresh water from seawater substantially as herein before described with reference to the accompanying drawings.

34. A process for desalination of water to produce fresh water from seawater substantially as herein before described with reference to the accompanying drawings.

35. A design configuration of a system for desalination of water to produce fresh water from seawater substantially as herein before described with reference to the accompanying drawings.

AMENDED CLAIMS

[received by the International Bureau on 18 December 2003 (18.12.03); originals claims 1-4 have been replaced – original claims 5 to 24 remain unchanged – original claims 33, 34, 35 have been cancelled.]

1. A process for desalination of sea water, incorporating barometric seals, to produce potable water by low pressure distillation at ambient temperature using sea water at different temperatures from different depth levels of the sea and using impinging swirl jets to produce fine particles for vapourisation.

2. A system for desalination of sea water, incorporating barometric seals, to produce potable water by low pressure distillation at ambient temperature comprising vapourisation system with special injection system, condensing system with heat exchanger, vacuum pumping system with vacuum chamber and combination of vacuum pumps and ejectors, cooling system to condense vapours using cold sea water taken from depth, plurality of jets to feed water as fine particles in the vaporizer, storage systems and instrumentation and control system.

3. A configuration of a system for desalination of sea water, incorporating barometric seal, to produce potable water by low pressure distillation using sea water at different temperature from different depth levels of the sea.

4. A system for desalination of sea water as claimed in claim 2 comprising the vapourising system as separate units or integrated unit with barometric seal.

5. A system as claimed in Claim 2 wherein the vaporizer and condenser are under vacuum for flash evaporation to take place at low pressures and temperatures.

6. A system as claimed in Claim 2 wherein there is provided a special

injection device for injecting warm surface water from the sea into vaporizer, the said jet or a group of jets atomise the feed water to fine particles to provide large surface area enhancing the rate of evaporation.

7. A system as claimed in Claim 2 wherein the said vaporizer has a barometric seal wherein the water which is not evaporated returns to the sea through a large long duct, the bottom of the said duct being immersed in the sea.

8. A system as claimed in Claim 2 wherein the vaporizer is positioned at a height more than the barometric height above the sea surface so that under operating vacuum condition the sea water raises and stays in the duct well below the injection plane thereby providing a seal to maintain operating vacuum in the vaporizer and continuously discharging the injected water which is not evaporated into the sea by gravity.

9. A system as claimed in Claim 2 wherein the condenser has a barometric seal and the said condenser being positioned at a height greater than the barometric height above the fresh water well.

10. A system as claimed in Claim 2 wherein the vacuum, the pumping system being configured as combination of jet ejectors and or vacuum pumps will have water jets for which primary driving fluid is being drawn from the inlet coolent water storage and supplied at the required high pressure by a high pressure pump.

11. A system for desalination of water to produce fresh water from sea water as claimed in Claim 2 comprising:

- means for collecting and storing warm sea water from the upper strata of the sea, cold sea water from the deeper cool strata of the sea and fresh water produced in the plant.

- vaporization means comprising a chamber and an injection device having plurality of jets to atomize the warm water into fine particles connected to said storing means for warm water.
- outlet means provided at the bottom of the said vaporization means for discharge of unutilized sea water into the sea.
- condensation means comprising a heat exchanger placed separately or integrally with the said vaporization means to condense the vapour produced in the above said vaporization system.
- means for supplying the cold water from ocean depth to heat exchangers, the said condensation means for condensing the vapour produced in the vaporization means and discharging this cooling water into the sea.
- means for creating vacuum comprising vacuum chamber and pumping devices connected to the said condensation means, vaporization means, and associated equipments.
- means for controlling for vacuum building, pressure, water levels and the flow rates of feed water and cooling water.

12. A system as claimed in Claim 11 wherein the said injection device comprises a series of impinging or swirl jets connected in series and placed inside the vaporization means.

13. A system as claimed in Claim 11 wherein the said means of storing the warm sea water is a water storage tank comprising of an inlet connected to a pipe having its open end immersed into the sea beyond two meter below the sea surface and the outlet is connected to the vaporization means through a pump or pressurization device to inject the feed water at desired pressure and flow rate.

14. A system as claimed in Claim 11 wherein the said means of storing the cold sea water are water storage tanks, comprising an inlet pipe having its outer open end placed below 150 m the sea depth and the outlet pipe is

connected to the condensation means through a pump or pressurization device for circulating the cold water through the heat exchanger in the condensation means.

15. A system as claimed in Claim 11 wherein the said the means of storing the fresh water are water storage tank comprising of a vertical duct with height more than the barometric height of fresh water and connected to the said condensation means and a vent for providing the atmospheric pressure over the fresh water storage in the storage tank.

16. A system as claimed in Claim 15 wherein the said duct provides the barometric seal to the condenser at the fresh water collection means.

17. A system as claimed in Claim 11 wherein the said vaporization means is having an outlet duct for discharging water which is not vapourised with its upper end connected to the bottom of the vaporization means and the lower end immersed in the sea at the depth below two meters from the sea surface and the duct having a height more than the barometric height above the sea surface.

18. A system as claimed in Claim 17 wherein the said outlet duct provides the barometric seal to the vaporizer.

19. A system as claimed in Claim 11 wherein the said vacuum pumping devices are ejectors and or vacuum pumps.

20. A system as claimed in Claim 11 wherein the said vaporizing and condensation means are operable by control means for regulating the cold water circulation through the heat exchanger in the condensation means and warm water injection into the vaporization means at the required flow rate.

21. A system as claimed in Claim 11 wherein the said means of controlling, comprises of feed back control systems with sensor and control devices.

22. A process for desalination of water to produce fresh water from seawater as claimed in Claim 1 comprising:

- filling the fresh water storage, cold water storage and warm water storage to the specified level.
- creating a vacuum in the vacuum chamber to reduce the pressure in the vaporization means and condenser means to the specified level.
- supplying the cold water from sea having the temperature below 20°C to the heat exchanger in the condensation means at the required flow rate to maintain required temperature as per process requirement.
- injecting the warm water from sea surface having the temperature above 20°C into the vaporization means at the desired flow rate through the injecting device.
- flash evaporating the injected warm water at the low pressure and directing the vapours to flow through the heat exchanger in the condensation means.
- collecting the unevaporated water at the bottom of the vaporization means and discharging the said warm water into the sea at required depth appropriately distributed for safe and sustainable marine ecological systems.
- condensing the vapours flowing through the heat exchanger and collecting the condensed vapours into the fresh water tank.
- controlling and maintaining the process parameters like water levels, water flow rates, vacuum and pressures according to the process requirements.

23. A process as claimed in Claim 22 wherein the temperature of the cold water circulated in the heat exchanger is below 20°C.

24. A process as claimed in claim 22 wherein the temperature of the warm water injected in the vaporizer is above 20°C.

25. A configuration as claimed in Claim 3 which has an injector configuration with a cavity having tangential entry of sea water and axial discharge of it as conical swirling jets into vaporizer.

26. A configuration as claimed in Claim 3 which has an injector module having a plurality of injectors arranged circumferentially in single or multiple rows at different radie around a central hub serving as such as a source for supply of the sea water at desired flow rates through radial flow paths to injectors with provisions to increase or decrease the number of injectors in the injector module.

27. A configuration as claimed in Claim 3 which has an injector module cluster having a plurality of injector modules mounted on a duct feeding the sea water to the injectors through the injector modules.

28. A configuration as claimed in Claim 3 which has an injector system having plurality of injector module clusters with identical coaxial injector module pairs facing each other and placed at distance apart in parallel planes enabling the swirling conical jets issuing from the injectors in one plane to impinch with corresponding swirling conical jet issuing from the other with provision for increase or decrease in the number of injectors.

29. A configuration as claimed in Claim 3 which has a manifold system feeding the sea water to the injection module cluster at the desired pressure and flow rates.

30. A configuration as claimed in Claim 3 wherein a vaporizer with a chamber of required volume with the injector system being suitably located inside the chamber and having appropriate inlet connection to the manifold system to feed the sea water and an outlet preferably at the bottom of the chamber, with a long duct connecting the outlet to the sea and the duct providing the barometric seal during operations.

31. A configuration as claimed in Claim 3 wherein a condensing system with plurality of condensers with shell and tube and or plate heat exchangers being connected to the vaporizer with proper ducts ensures smooth passage for the vapours produced in the vaporizer to the condensers and ensures complete condensation of all vapours as fresh water.

32. A configuration as claimed in Claim 3 wherein a vacuum pumping system with vacuum pumps and ejectors being connected to plurality of vacuum bottles and the condensers for maintaining the desired vacuum pressure in the condenser and vaporizer.

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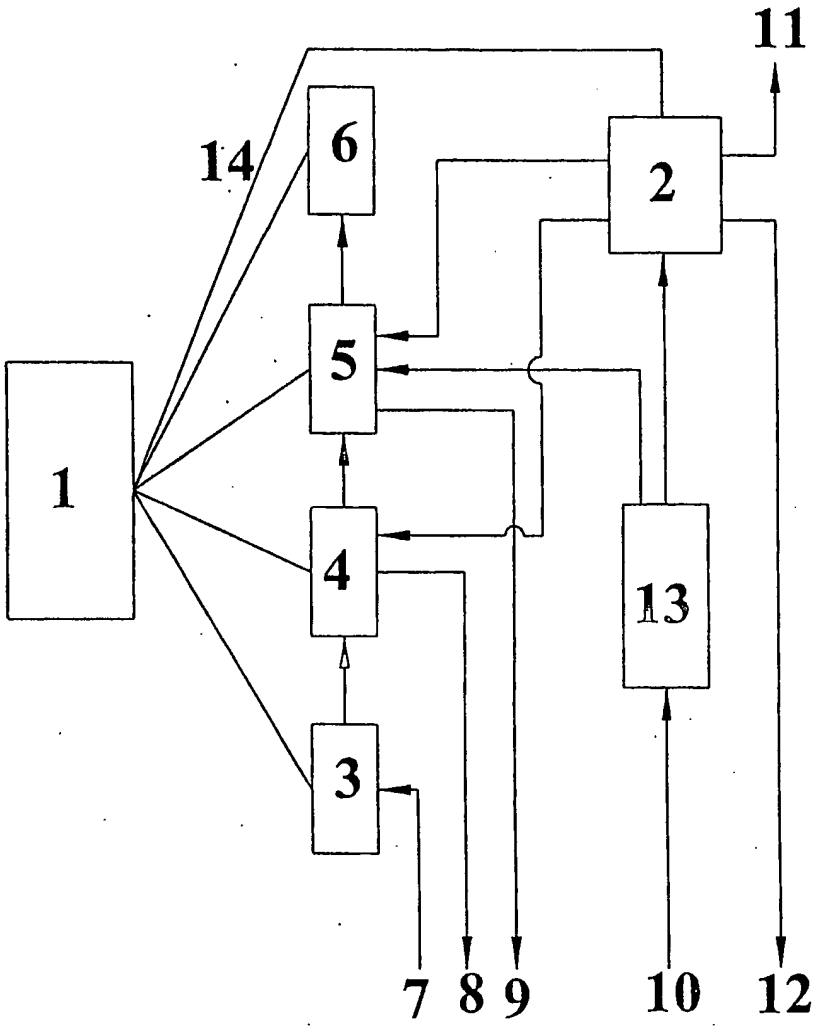

FIGURE-1

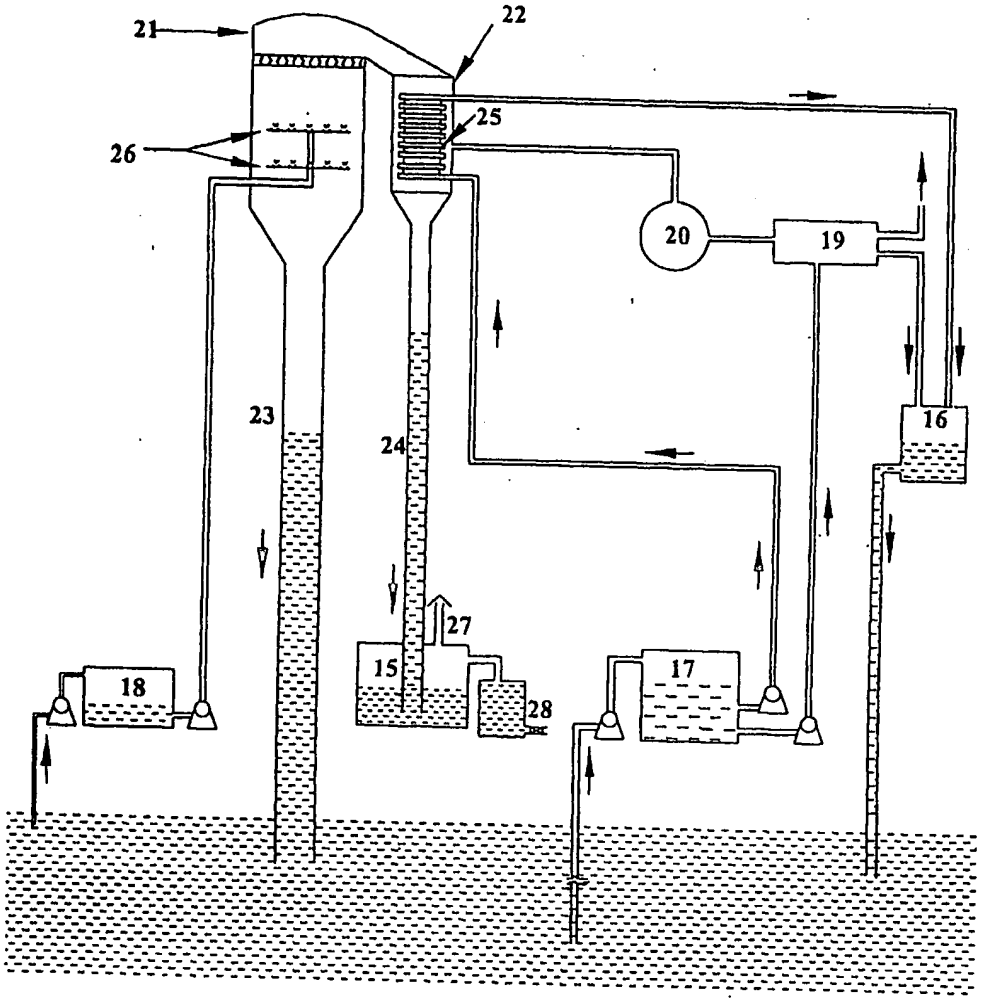

FIGURE-2

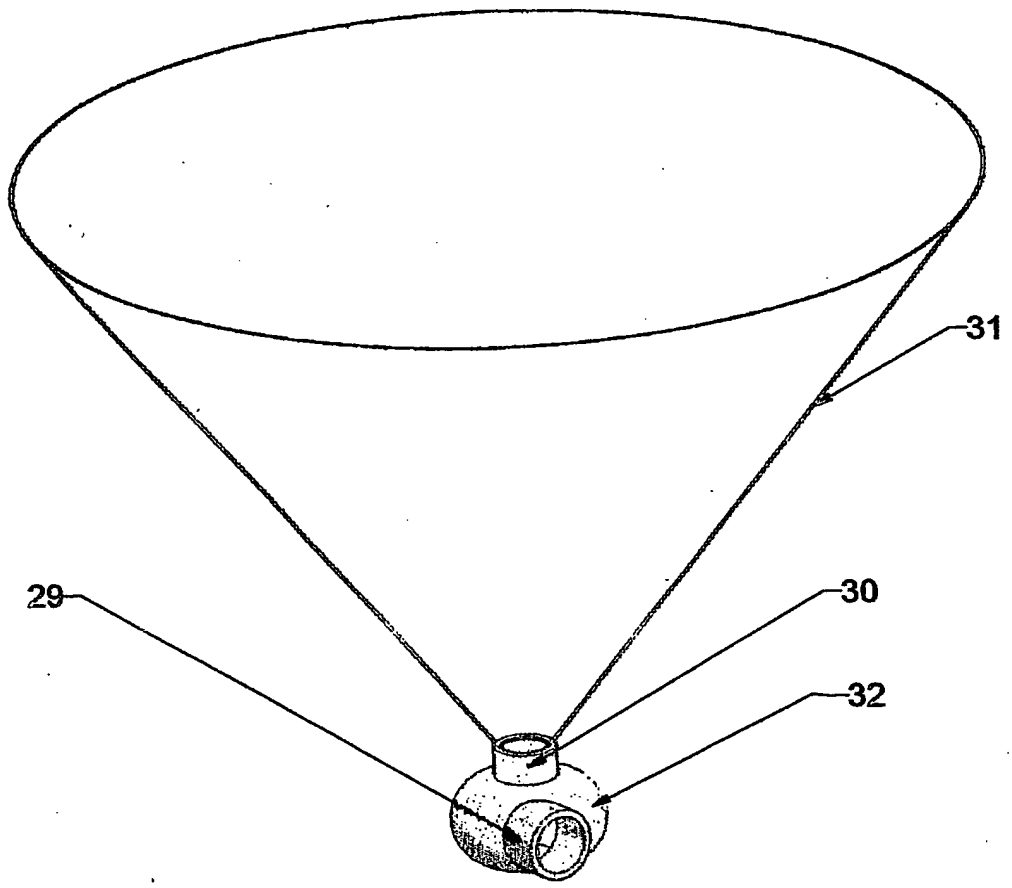

FIGURE - 3

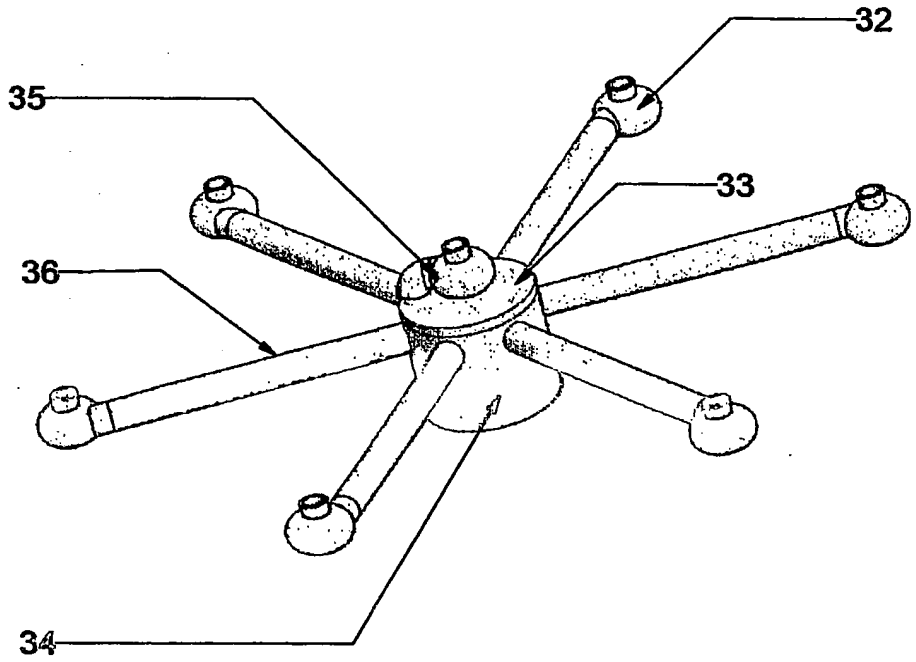

FIGURE - 4

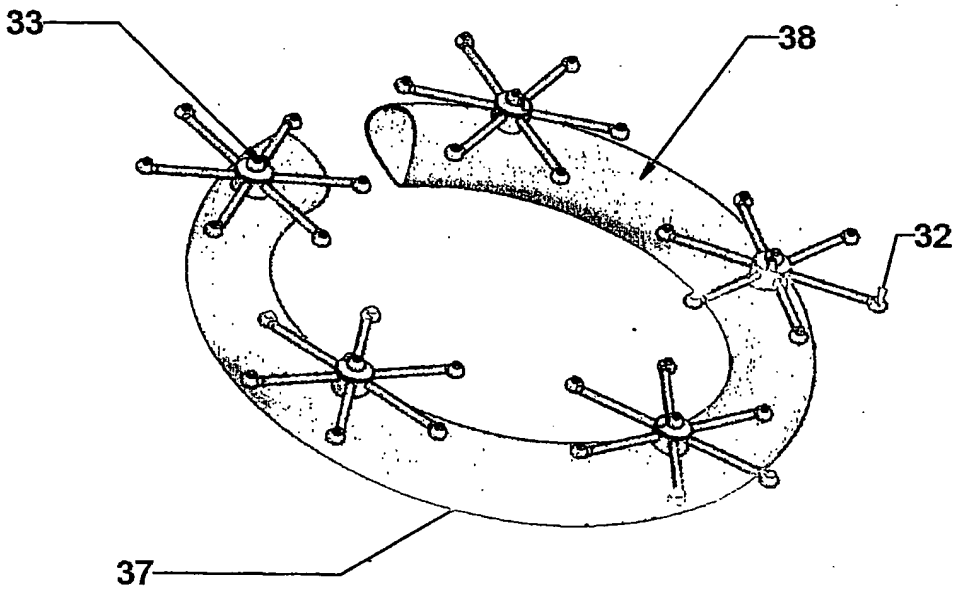

FIGURE - 5

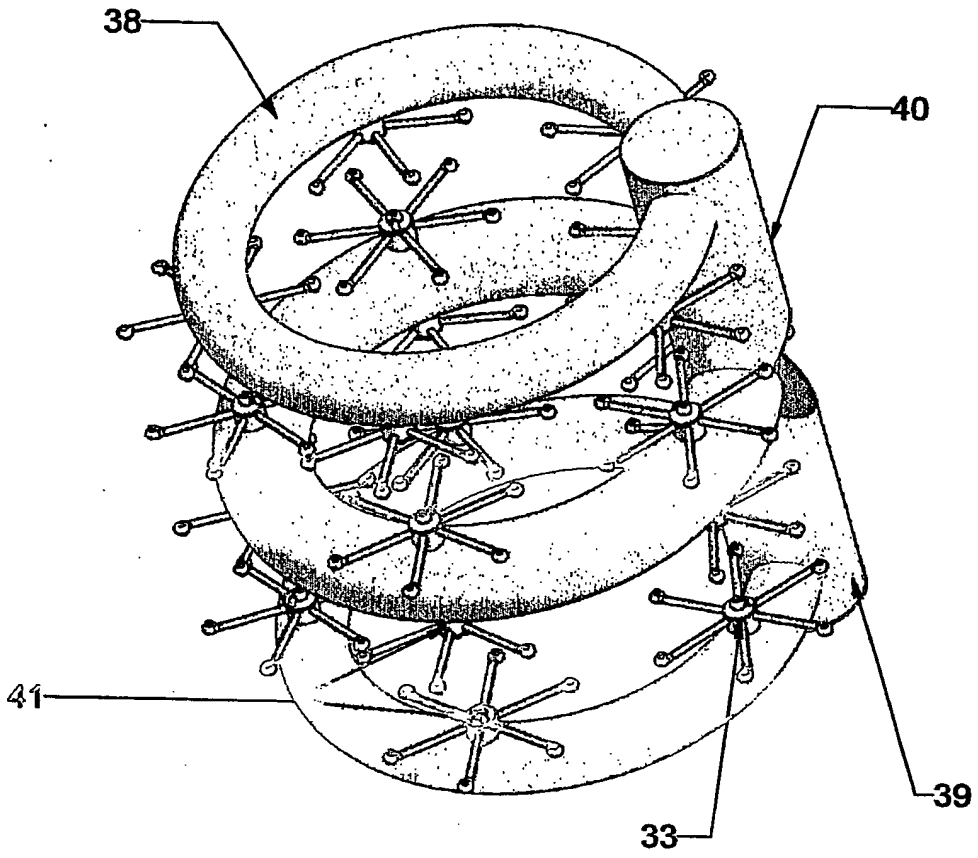

FIGURE - 6

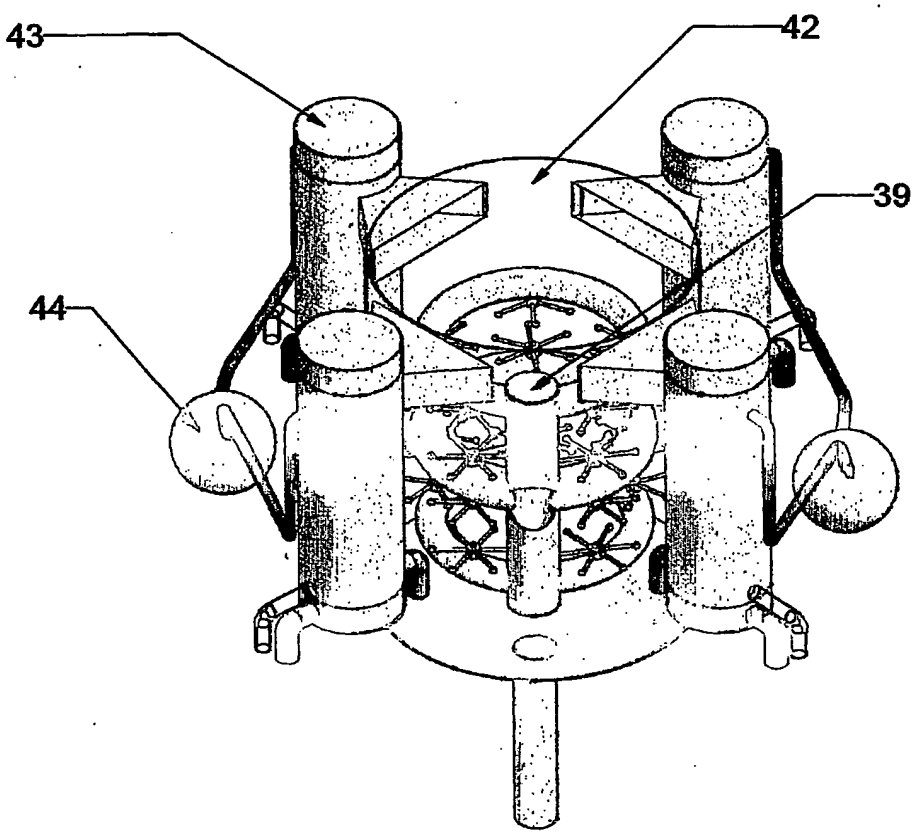

FIGURE - 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IN 03/00034-0

CLASSIFICATION OF SUBJECT MATTER

IPC[7]: C02F 1/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC[7]: C02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPOQUE; WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3347753 A (MORSE) 17 October 1967 (17.10.67) *column 1, lines 12-61; claims 1-2; figure 1.*	1,2,4-6,11
Y		7-10,12-21
Y	WO 80/00833 A1 (PROJECTUS INDUSTRIPRODUKTER AB) 1 May 1980 (01.05.80) *abstract; page 1, lines 4-13; page 2, line 8 - page 5, line 12; claims 1-4; figure.*	7-10,12-21
Y	US 2490659 A (SNYDER) 6 December 1949 (06.12.49) *column 1, lines 1-25; claims 1-7.*	7-10,12-21

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
„A" document defining the general state of the art which is not considered to be of particular relevance
„E" earlier application or patent but published on or after the international filing date
„L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
„O" document referring to an oral disclosure, use, exhibition or other means
„P" document published prior to the international filing date but later than the priority date claimed

„T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
„X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
„Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
„&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 September 2003 (15.09.2003)	22 October 2003 (22.10.2003)
Name and mailing adress of the ISA/AT Austrian Patent Office Dresdner Straße 87, A-1200 Vienna Facsimile No. 1/53424/535	Authorized officer KOLLER G. Telephone No. 1/53424/458

Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IN 03/00034-0

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: 3,25-35
because they relate to subject matter not required to be searched by this Authority, namely:
see extra sheet

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IN 03/00034-0

Concerning BOX I:

Claims 3 and the related claims 25 - 32 concern an arrangement of the plant (design configuration). Although the claims are characterized by technical features of parts and details of the plant, a design does not depend on technical features. It is not possible that the e.g. a "method of phase change" is connected with an arrangement of vaporizers, vacuum pumps, jets, etc.
Claims 33 to 35 do not specify any technical features but only refer to the description and drawings.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/IN 03/00034-0

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